Appln No.: 10/005,452
Amendment Dated: May 10, 2004
Reply to Office Action of January 14, 2004

REMARKS/ARGUMENTS

This is in response to the Office Action mailed January 14, 2004 for the above-captioned application. Reconsideration and further examination are respectfully requested.

Applicants request an extension of time sufficient to make this paper timely and enclose the fee. The Commissioner is authorized to charge any additional fees or credit any overpayments to Deposit Account No. 15-0610.

The title has been amended consistent with the Examiner's suggestion. To facilitate later processing of the application, an Application Data Sheet reflecting this change is also enclosed.

Claims 1-30 were rejected under 35 USC § 112, second paragraph, as indefinite. Applicants have amended the claims in view of the Examiner's remarks. In particular, claim 1 and 16 have been amended to recite "... between 50 and 85% of the total mixture by weight of metal particles, said metal particles consisting of particles of antimony and optionally particles of Group VIII metals, particles of additional Group VA metals other than antimony, or both ." It is believed that this amendment, which is consistent with the specification, answers the rejection, and that the rejection therefore should be withdrawn. In addition, claims 2 and 17 have been amended to correctly refer to the metal particles of the previous claim.

The Examiner also rejected the claims based on the units of resistivity in claims 1 and 16, asking the question, K-ohms per square what. It is respectfully submitted that units as recited are correct and would be understood by the person skilled in the art. Enclosed for the Examiner's consideration are copies of two web site articles (www.esdjournal.com/techpaper/ohms.htm and www.esdnw.org/Newletters/01-10-01%20Newsletter/NL010104.htm) which explain this usage of units. As noted in these publications, surface resistivity is reported in ohms/square and is applicable to very think surface materials. Note that "resistivity" is different from "resistance" and this is the reason that the units of dimension drop out and the value is independent of the size or units of the square measured. Accordingly, the rejection under 35 USC § 112, on this basis should be withdrawn.

Claims 27-30 were rejected under 35 USC § 112, second paragraph and 35 USC § 101 because they recited a use. The claims have been amended to recite positive method steps.

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For these reasons, this application is now considered to be in condition for allowance and such action is earnestly solicited.

Respectfully Submitted,

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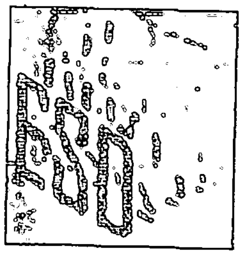
Attachments:
Two Web Site Print outs.
Application Data Sheet
Extension of Time request
Credit Card Payment Form



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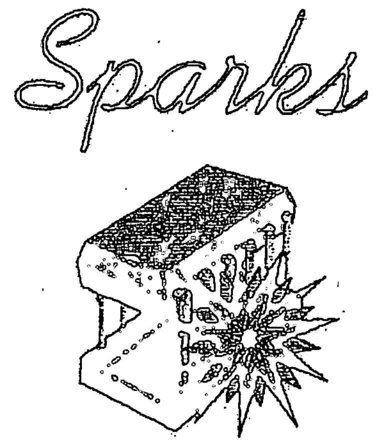

What Does it All Mean?

By Bill Metz

???RESISTIVITY?...RESISTANCE?....SURFACE?.....VOLUME?......OHMS PER SQUARE????

After opening the door to understanding Electrostatics (and ESD in particular), quickly we are called upon to offer engineering judgments on materials (and packaging materials in particular). Most company ESD specifications offer a brief explanation on what they choose for characterizing materials from an electrical performance point of view. For example, most believe in the usage of shielding materials for transport outside of an ESD Protective Area, and, in Sec 6.6.2, discussion is had re: electrical characterization tests (Capacitive Probe, Charge Generation, Static Decay, Surface Resistance and Surface Resistivity).

Now, the ESD Assoc. has replaced "Surface Resistivity" with "Surface Resistance" (EOS/ESD STD S11.11; VOLUME RESISTANCE is forthcoming in S11.12), but, moreover, what is the difference between surface "resistance" and "resistivity" and why the weird units of measure, "ohms/square", (Ohms per square what?...cm2 or square inch or what??)........

Surface resistivity is used to describe the electrical resistance of the surface of the material..... "How thick is the surface?" (Answer = very thin) "What about non-homogeneous layers?" (Answer = no way; only homogeneous stuff applies.) "Isn't there some formula that relates resistance and resistivity?" (Yes):

R = p (L/W) (R = Resistance, p= Surface Resistivity, L = Length, W = Width)

Now, quite neatly, when L=W (viz. a square), R = p ..... Hence, it does not matter what L or W are, so long as they are equal. Surface resistivity is defined for a square surface and thus has units of ohms per square; it is quite independent of the size of the square (a dimensionless term). Lastly, we see Resistance comes out cleanly in units of Ohms which, indeed, it should; and we have not violated Ohm's Law whereby R = V/I.

As one would imagine, several things can cause measurement discrepancies: Humidity, surface contamination (e.g. surfactants), alternative electrical paths through the material. Note that charge generation characteristics (tribocharging) are independent of resistance and are determined separately.

HP classifies materials' Surface Resistivity thusly:

Shielding: < 1.0 x 10E4 ohms per square
Conductive: < 1.0 x 10E5 ohms per square
Dissipative: > 1.0 x 10E5 but < 1.0 x 10E11 ohms per square
Insulative: > 1.0 x 10E11 ohms per square [I added.]

And, for Surface Resistance:

Shielding: < 1.0 x 10E3 ohms
Conductive: < 1.0 x 10E4 ohms
Dissipative: > 1.0 x 10E4 but < 1.0 x 10E10 ohms
Insulative: > 1.0 x 10E10 ohms[I added.]

[Why the 10X difference between Resistivity and Resistance limits? Nothing magical; but the geometric configuration of the circular electrodes in the ESD STD S11.11 causes this to occur.]

Sometime later we will discuss the importance of VOLUME RESISTANCE measurements. New tests are constantly being developed (e.g. "Charge Retention" is in study), but, over the years, Surface Resistance has been among the most useful tests. One last point concerns "shelf life": HP expects that the ESD control protective properties of qualified materials must last at least one year at 30° C, 15- 95% RH; the non-charging trait of many dissipative materials may last less than this, so care must be used in their selection.

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Good Afternoon! It is currently 1:23 PM on Tuesday, January 20, 2004.

Ohms Per Square What!

By Gene Chase, ETS, Inc.

Is it ohms per square meter or ohms per square inch? Which is it? Actually, it is none of these, but "**ohms per square anything**." However, this confusing term that has been used to describe the **Surface Resistivity** (ρ) of a material. Is it here to stay forever? The ESD Association Glossary, ESD-ADV 1.0-1994 (1), describes **Surface Resistivity** in the following way: "For an electric current flowing across a surface, the ratio of DC voltage drop per unit length to the surface current per width. In effect, the surface resistivity is the resistance between two opposite sides of a square and is independent of the size of the square or its dimensional units. Surface resistivity is expressed in ohms per square. When using a concentric ring fixture, resistivity is calculated by using the following expression, where D1 = outside diameter on an inner electrode, D2 = inside diameter of the outer electrode and R = measured resistance in ohms: (from EOS/ESD-S11.11 - 1993)(2)."

Surface Resistivity **$(\rho_s) = \{2\pi/[\ln(D1/D2)]\}R$**

Some have asked, why use this allegedly ambiguous term and measurement? Can't we just use ohms? Because of the geometry of the EOS/ESD-S11.1 concentric ring electrode, the resistance is simply **$\rho_s/10$ ohms**. One could further argue, why not just always use this resistance in ohms result?

In order to answer these questions, we need to examine the history of **ohms per square**. For a number of years the **surface resistivity** was a pure number with no dimensions. Valdes (3) in 1954, wrote about the four-point probe method to make resistivity measurements on germanium transistors. However, all this work, and later work by Uhlir, (1955)(4), assumed a three-dimensional structures with one infinite dimension. Their work was expanded by Smits (5) in 1958 for two-dimensional structures. Smits defined a four-point probe method of measuring "**sheet resistivities.**" This work eventually became an industry standard for measuring the resistivity of diffused layers in semiconductors. He developed correction factors for measuring sheet resistivities on two-dimensional and circular samples using a four-point probe where the two outer probes source current and the two inner probes measure voltage. He found that this method was not only useful for measuring diffused surface layers, but was useful in obtaining "**body resistivities**" of thin samples. Yet in all this work **sheet resistivity (ρ_s)** had no dimensions, but was a pure number. Although Smits showed that body resistivity (ρ) was equal to sheet resistivity (ρ_s) times w, where w is the thin sample thickness, he did not assign the dimensions, **ohm-cm**, to this resistivity. The term he called "body resistivity," we now commonly call "volume resistivity" or "bulk resistivity." It is interesting to note that in Smit's work that he never uses the term "sheet resistance." He developed the relationship that:

Sheet Resistivity **$(\rho_s) = V / I\ (\pi/\ln 2) = V / I\ (4.5324)$**

In 1962, Irvin (6) developed curves showing the **resistivity in ohm-cm**, versus Impurity concentration of various doping levels in silicon. Here he defined the "**bulk resistivity**" as **ohm-cm**. The resistivity is again dimensioned as **ohm-cm**. There is no mention in this publication of sheet resistance or ohms per square.

In 1968 in a book by Berry, etal. (7), the authors state that the resistance of a thin-film resistor is directly proportional to the resistivity, ρ , and inversely proportional to the thickness, **d**. They introduce the term "**sheet resistance (Rs)**" to define thin film resistor parameters. They define it as:

$$Rs = \rho / d$$

The authors further explain that the **sheet resistance** may be thought of as a material property since the film is essentially two-dimensional. Therefore, a simple thin film resistor consisting of a simple rectangle of length **l** (in the direction of the current) and the width **w** has a resistance of:

$$R = (\rho / d)\ (l/w) \text{ or}$$

$$R = Rs\ (l/w)$$

The authors claim that the term **(l/w)** is sometimes called the number of squares in the resistor, since it is equal to the number of squares of side **w** that can be superimposed on the resistor without overlapping. They assert that the term "squares" is a pure number, having no dimensions. The author's state that the sheet resistance has the unit of ohms, but it is convenient to refer to it as "**ohms per square**" since the sheet resistance produces the resistance of the resistor when multiplied by the number of squares. They go on to say that the concept can be broadened to include any arbitrarily shaped resistor by calling the quantity **Rd/ρ** the effective number of squares. The authors expand on the use Smit's four-point probe technique and introduce new correction factors for the size of their substrate. It turns out that the four-point probe is a useful tool to check the uniformity of thin-film resistors.

The term "**sheet resistance**" has not only shown up in defining materials to control ESD. It is also used to define resistive seas and overcoats of all types including the coatings on cathode ray tube (CRT) monitors to reduce the second anode electric fields that could be coupled to a person touching the screen. It is also used to describe the resistance of the semitransparent layer that composes one terminal of a liquid crystal display (LCD). The term continues to be used to define the resistance of both thick and thin-film resistors. In a notable book on the physics of semiconductors by Sze (8) in 1981, the term **sheet resistance** is not found to describe the characteristics of semiconductors. Only the term **resistivity** is used.

So now you know where the dimension "**ohms per square**" apparently originated. It appears that we are stuck with this term unless the authors of the ESD Association Glossary decide to redefine it and use only the dimensions **ohms** and **ohm-cm** for surface and body (volume or bulk) resistivity respectively.

Therefore, it would seem reasonable that **surface resistivity** should always be measured in **ohms** and **volume resistivity** in **ohm-cm**, as Jonassen (9) has argued for a number of years.

Maybe we should leave the term **sheet resistance** and **ohms per square** to the thick and thin film resistors and hybrid integrated circuit people, where it makes some sense to them and stick to using **ohms**.

References

1. ESD ADV1.0-1994, ESD Association Advisory for Electrostatic Discharge Terminology - Glossary
2. ANSI EOS/ESD S1.11-1993, EOS/ESD Association Standard for Protection of Electrostatic Discharge Susceptible Items - Surface Resistance Measurement of Static Dissipative Planar Materials.
3. Valdes, L., Resistivity Measurements on Germanium transistors, Proceedings I.R.E., 42, Feb.1954, p420.
4. Uhlir, A., The Potentials of Infinite Systems of Sources and Numerical Solutions of Problems in Semiconductors Engineering, Bell System Technical

Journal, Jan 1955, p105.

5. Smits F.M., Measurement of Sheet Resistivities with the Four-Point Probe, Bell System Technical Journal, May 1958, p711.
6. Irvin, J.C., Resistivity of Bulk Silicon and Diffused Layers in Silicon, Bell System Technical Journal, 41,p387, (1962).
7. Berry, R.W., Hall, P.M., Harris, M.T., "Thin Film Technology", Van Nostrand Reinhold Company, New York, NY, 1968.
8. Sze, S.M., "Physics of Semiconductor Devices", John Wiley and Sons, New York, NY, 1981.
9. Jonassen, N., "Electrostatics", Chapman and Hall and International Thomson Publishing, New York, NY,1998.